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BRIEF INTRODUCTION TO LOW ORBIT SATELLITE MOBILE COMMUNICATIONS SYSTEMS

Wang Jingquan

As far as satellite communications are concerned, after satellite systems in geosynchronous orbits occupying the commanding position for 30 years, we are just about to enter into the epoch of low orbit satellite constellation communications. With respect to the appearance of low orbit satellite mobile communication systems, it is possible to say that they have appeared on a foundation of the fast developments in small satellite technology, satellite launch technology, surface cellular communications technology, as well as electronics technology, and so on. This type of system is a first step toward the "world village" and is going to become an epoch making milestone in the history of satellite communications.

Low orbit satellite communications systems can be called an inverted cellular type system. In traditional surface cellular type communications networks, the basic equipment is on the surface. The cellular area is fixed. Mobile users "wander around" in these areas realizing communications. However, the basic facilities associated with low orbit satellite communications systems are in space. The positions of small cellular areas change relative to the spin of the earth. User movement and satellite movement speeds are compared to each other. Users can then be seen as stationary.

With respect to making use of this type of system, it goes without saying that, in any corner of the globe--including remote regions where communications are difficult or there is no electric power supply--people will all be able to carry out global communications or short range communications.

I. System Characteristics

In general, communications satellite systems can be divided into three types--that is, stationary orbit satellite systems (orbital altitudes are approximately 36000km), large elliptical orbit satellite systems (apogee altitudes are approximately 20000km), and low orbit satellite systems (orbital altitudes are 300-3000km).

The primary advantage of geostationary orbit satellites is that orbits are high. As a result, one satellite is capable of covering 30% of the earth's surface. Use can be made of it 24 hours a day. Global coverage only requires 3 satellites. The drawback is that satellites are only able to be placed into equatorial plane orbits with altitudes of 36000km. Morever, this limited orbital resource is now very crowded. This type of satellite can generally only cover areas with geographical latitudes less than 70°. Making use of this type of satellite, the areas of the two poles will appear as communications blind spots. Due to the fact that orbits are high, signal transmission ranges are long. This necessarily makes space transmission losses relatively great. Signals reaching the surface are weak. The surface must use comparatively large antennas to recieve. One way satellite to surface signal transmission time delays are then 270

microseconds. Maintaining the satellite "stationary orbit" position requires using up 90% of the fuel which satellites carry. In order to increase operating life, satellites are made bigger and bigger.

The greatest advantage of large elliptical orbit satellite systems is that it is possible--on the basis of coverage requriements--to design satellite apogees. It is thus possible to resolve the problem of covering the polar areas. However, the weaknesses associated with high altitude orbits cannot be overcome.

Low orbit satellite systems opt for the use of low orbits and mulitiple satellites to form constellations. Therefore, low orbit satellite constellations systems have obvious characteristics and advantages. The orbital altitude is low. Signal powers transmited to the surface are large. It is possible to realize individual mobile communications associated with receiving systems which are very light and convenient. Through selecting the number of satellites associated with constellations, orbital altitudes, and angles of inclination, it is possible to actively determine coverage areas and motion cycles. There is no need to correct orbital north-south directional deflections, saving fuel. Satellite weight is lowered. It is possible to opt for the use of small satellites. Low orbit constellation satellites are distributed in several orbital planes. Therefore, users in any corner of the world at any instant can at least be seen by one satellite. Moreover, links between satellites will also connect up this satellite to other satellites, making a multiple satellite constellation link up into a whole. As a result, this type of satellite constellation is not only capable of realizing global coverage but also capable of realizing regional coverage. It is not only capable of real time communications. It is also capable of time delay communications. Influences from satellite malfunctions are relatively small. After one satellite develops a malfunction, it is possible to relatively quickly launch a replacement (illegible) or orbital adjustment. Option is made for the use of cellular coverage beams to realize more effective multiple frequency utilization than stationary orbit satellites (space isolation).

In summary, low orbit satellite constellations not only conentrate the advantages of low orbit satellites--saving power, carrying less propellant, and smaller satellites being easier to launch--but also concentrate the large coverage areas of geostationary orbit satellites (making use of constellations and links between satellites equivalent to one very large model satellite) being capable of providing the advantages of real time continuous communications. They also focus advantages associated with large ellicptical slanted orbit satellites resolving the masking and attenuation problems associated with high latitude area individual and mobile communications.

II. System Structures and Basic Operating Processes

1. System Structures

Low orbit satellite constellation communications systems are composed of satellite constellations, main control stations (connected to 11 [illegible] stations), and users terminals. Some system main control stations are combined (illegible). Some systems are separated. However, the basic functions are roughly the same.

Main control stations generally include three sections--telemetry, tracking, and remote control (simply called TTC). At the same time, they also include the technological operating control center (simply called TOCC). TTC monitors the flight status of all satellites, maintains ephemeris, and controls adjustments to satellite orbits in order to maintain satellite constellation geometrical relationships. TOCC, by contrast, controls communications channel distribution, controls changing connections between satellites, and prevents communication frequency clashes, maintaining capacity. The 11 transfer stations are then the switching stations associated with satellite systems and ground systems, controling the establishment and cancelation of calls, providing Doppler frequency shift calibration activities for user terminals, and so on. /20

2. Orbital Selection

The core of constellation communications systems is naturally satellite constellations. Since constellations are formed from multiple satellite structures, orbital selection is then extremely key.

First of all is orbital altitude. Outside China, several systems have already been put forward. Orbital altitudes are all in the range of 500-1500km. The reason is that, if orbits are lower than 500km, they are subject to atmospheric drag perturbations. Atomic oxygen (illegible) corrosion is relatively great. Orbiting fragment densities are comparatively large. Above 1500km, radiation from the Van Allan radiation belts is relatively severe.

The second factor for consideration is satellite orbital eccentricities and angles of inclination--designed on the basis of communication coverage requirements.

As the third factor, consideration must be given to satellite beam link ups and continuous coverage. In order to guarantee continuous coverage of the two polar regions, in conjunction with this, it makes blind spots not appear between satellites.

The fourth factor is to consider the number of orbital planes and the number of satellites in each orbital plane. This involves economic and technological factors. If all the satellites in an orbital plane are launched at the same time, the fuel needed in order to correct the relative positions between satellites is minimal. Each orbital plane requires independent satellite launches. As a result, in situations where continuous coverage is guaranteed, the fewer the orbital planes are the better.

3. Basic Operating Processes

In low orbit satellite constellation systems, all numerical processing of information and channel switching is completed in orbit in all cases. Information cut over from one satellite to the

next satellite is, in reality, more convenient than the signal cut over between surface cellular areas. The reason is that, in surface cellular systems, the system has no way to know the direction of user movement before the fact. If the user attempts to cut over signals to an adjacent cellular area, but the user just changed directions and entered into another cellular area, it is then possible to have the appearance of call "No Connection". In low orbit satellite constellation systems, for any means of transport--even if it is aircraft--there is no way for it to compare in speed to satellites. The moving "cellular" acquires a stationary user. The system is made active. Signal cut over will, of course, be much more convenient. Low orbit satellite system users are capable of calling any telephone number on earth. It is possible to connect to variou types of lines almost immediately. When telephones associated with other systems call low orbit satellite system users, calling only requires knowing the telephone number of the called party. After the number unit is positioned by the system, the connection station which stores a list of all the users will connect through to the user's telephone.

The simple process associated with calling and channel switching is call request, the system going through user legality determination, inquiry for the roving position of the called user, cutting over communications channels on the basis of call request address information, and either cutting over within the coverage area of one satellite or cutting over again to another satellite through links between satellites. Computers on satellites carry out demodulation and modulation on received signals and then, on the basis of ephereris and user roving location, sends out signals.

III. Key System Technologies

1. Satellite Constellation Orbital Structure

The first step in designing low orbit satellite constellations is nothing else than precisely determining the geometrical structure associated with the constellations. Low orbit satellite constellations are divided into two types--fixed relative position and random constellation. Fixed relative position constellations possess satellite structures associated with fixed relative positions in terms of time. It is necessary to carry out orbital control with respect to each satellite, using differences in the number of satellite orbital spares to form different optimal constellation structures. Due to imprecision in the launching of satellites into orbit as well as satellite drift given rise to by various types of orbital perturbations, if orbit control is not carried out with regard to satellites, constellations then turn into random constellations. Random constellations make orbital control very simple because they are capable of saving on orbital calibrations after launch. There is still, however, a requirement for many satellites. As far as these two types of satellite constellations--possessing the same functions--are concerned, the former requires several score of satellites and the latter requires several hundred satellites.

The Iridium system opts for the use of a fixed relative position satellite constellation. The principles for the selection of actual orbits are: opting for the use of minmum orbital planes and numbers of satellites and also being able to guarantee continuous coverage; designing small satellites to realize the lowest investment; designing rational link redundancy to make small satellites capable of direct communications with user terminals at low powers; selecting appropriate orbital altitudes to make satellites not only subject to small amounts of Van Allan radiation but also subject to small atmospheric drag influences. On the basis of the principles above, the Iridium system selected 765km orbits. As far as the intervals associated with 7 orbital planes on the equator--besides the 1st and 7th orbital planes, which are 17.5°--are concerned, the distances between other orbital planes is 27.1°. The satellite intervals within each orbital plane are 32.7°.

2. Network Topological Structure

There are three types of designs associated with the network topological structure of low orbit satellite real time communications. The first type of design is limited to local communications. Option for its use is appropriate when users are located in the coverage area of one satellite at the same time. The second type of design can be used in local and global communications. However, it requires earth stations which are sufficient in number. The third type of design opts for the use of links between satellites. It can not only be used in regions. It can also be used in global communications. At any instant, users can see at least one satellite. It is capable of supplying continuous coverage with regard to service areas. Users positioned in the service area of the same satellite communicate directly. Users located in the coverage areas of different satellites communicate through links between satellites. This type of network structure requires continuously and precisely determining the location of each satellite. Network management can be concentrated in earth stations. It can also be distributed on satellites. Users can be fixed type and mobile type. They can also be the 11 netted stations on the surface. The Iridium system opts for the use of the third type of network topological structure design.

3. Cellular Management and Frequency Reutilization

Using Iridium satellites as an example, the 6 side surfaces of the satellites are all fitted with phase control array radars. Each side surface can send out 6 beams, forming a small cellular coverage zone as a 6 sided figure on the surface. The bottom parts of satellites are also equiped with a ring shaped dipole antenna, sending out a beam. In this way, one satellite /21 forms 37 small cellular zones on the surface. The diameter of each small cellular zone is 686km. The diameter of the coverage area of one satellite is 4074.4km. The time period when each satellite is visible passing overhead is 9 minutes.

Satellite antenna arrays opt for the use of fixed time methods of scanning. Through programed controls, scanning beam antennas are made to point at corresponding cellulars during specified periods

of time. When satellites move toward the polar regions, the distances between satellites on adjacent orbital planes are reduced, causing antenna direction diagrams to link up. At this time, option is made for the use of methods making a certain beam antenna not send out signals and forming a new cellular frequency reutilization relationship. This type of synchronous cellular control is defined as cellular management.

The Iridium system forms 1628 individual cellulars over the whole earth. In accordance with 7 cellular frequency reutilization methods, each frequency can be reused over 200 times. Within the range of the U.S. alone, it is possible to realize reuse of frequencies more than 5 times. At the present time, there are still no other systems which have space frequency spectrum utilization efficiences as high as this.

As far as frequencies requested by the Iridium system are concerned, for mobile user up and down links, option is made for the use of 1610-1626.5MHz, 11 connection stations, and satellite control center utilization frequencies (also called presentation link frequencies). Up link 27.5-30.0GHz. Down link is 18.8-20.2GHz. Link frequency between satellites is 22.55-23.55GHz.

The Iridium system up link is composed of 102 channels at intervals of 160kHz. Each channel only has a band width of 126kHz. It is estimated that it is possible to make use of 64 carrier waves at most. Among these, 9 are used as control channels.

Down links are composed of 46 carrier waves. Carrier wave intervals are 350kHz. Each channel occupies a bandwidth of 280kHz. It is estimated that it is possible to make use of 29 carrier waves at most. Among these, 4 are used as control channels. In order to reduce bandwidth, down links opt for the use of digital speech interpolation (DSI) technology. Option is made for the use of 2.2:1 DSI activation compression ratios, making 25 down link service carrier waves capable of handling 55 speech channels. 4 control channels provide DSI control information to mobile user terminals. In conjunction with this, group call and synchronous signals are provided. The arrangement of this type of carrier wave frequency spectrum is in order to prevent interference between radioastronomy signals (1610-1613.5MHz) and independent combinations of navigation satellite signals (GLONASS reaches 1616MHz at a maximum).

MISSIONS CARRIED OUT BY THE GALILEO PROBE

He Ying (Trans.) Xue Fuxing (Ed.)

On 8 December 1992, when the Galileo probe went through earth orbit perigee, there was only a 1.5km deviation from the originally determined point. Time was only off 0.1 seconds. Due to reducing the number of iterations of orbital corrections required, when the Galileo had completed detection tasks, the propellant remaining increased from the predicted 4-5kg to 18-19kg. This then provides more options for mission planners. It is possible to increase the scientific data detected.

Scientific detection and engineering tasks which the Galileo probe has recently carried out include:

1. Carrying out measurements of such things as the earth's magnetic field, plasma, dust, high energy particles, as well as heavy ions, and so on, when the head shock wave from the solar wind relative to the magnetic tail brushing by the earth penetrates through the earth's magnetic layers.

2. Carrying out observations with respect to the solar wind together with other solar system probes. The time is the period of one solar rotation--28 days.

3. Carrying out investigations with regard to probes because they will subsequently fly into the atmosphere of Jupiter.

4. Calibrating scientific instruments using already known targets in the earth moon system, and, a the same time, also carrying out measurements with respect to the levels of influence between various types of instruments.

5. Making a mosaic map of the north polar region of the moon. These images opt, in the first instance, for the use of high precision solid state cameras with modernized optical spectrum ranges exceeding 0.4-1 microns taking pictures from space.

6. Drawing up the first batch of infrared maps of the north polar region of the moon. These pieces of infrared and visible light information are capable of providing data for the study of

the terrain structures associated with these regions--including the amounts of water in minerals.

7. Taking color mosaic imagery of the Andes mountains and Hawaii.

8. Taking ultraviolet nomograms around the moon in order to find oxygen, hydrogen, and hydrogen-oxygen compounds, and, in conjunction with this, measuring the reflection factors of the moon.

9. Observing polar lights, lightning, city lights, and other weak lights appearing on the back side of the earth to use in comparisons with observed lightning structures on Jupiter and Venus.

10. Taking infrared imagery of the north and south poles of the earth in order to gather environmental data related to ozone and carbon dioxide.

11. From 8-10 December, when leaving the earth, carrying out photography of the earth using color film.

12. On December 16th, Galileo's carrying out photography of the moon using color film during periods of stellar ecllipse.

13. 9-16 December, carrying out deep space laser communications technology tests.

U.S. WILL CARRY OUT IMPROVEMENT PROJECT ON TOMAHAWK MISSILE

Ying Hui

The U.S. Defense Department expects to carry out a Tomahawk missile modernization project this fall aimed at improving the flexibility and reaction capabilities of the missile in question.

Tomahawk improvement plans lay emphasis on technological improvements associated with the weapons system in question. Among these are included opting for the use of warheads possessing the capability to penetrate hardened targets as well as new guidance systems. This improvement project is also capable of spuring the redoing of antiship types of Tomahawk missiles. In conjunction with this, 1700 new model missiles will be produced.

The project in question will carry out requests for bids this fall. In conjunction with this, contractor contracts will be signed in the spring of 1994. Engineering, manufacture, and test production phases are scheduled to last 4 years. The producers of Tomahawk missiles at the present time--the McDonnell Douglas Co. and the Hughes Missile Systems Co.--will open competition for this contract.

At the present time, when Tomahawk missiles are carrying out missions, it is necessary to do imagery of target areas, map them out, and do digital processing of data, etc. It is necessary to change this type of guidance method. To improve Tomahawk missile flexibility, there is a need to alter missile guidance equipment, turning to an option for the use of synthetic aperture radar, millimeter wave radar, or infrared imagery detectors. Another method for improving flexibility is nothing else than the adding of missile capabilities to communicate with "third parties". As far as the Tomahawk missiles currently on hand are concerned, after launch, it is not possible to have contact with them. After going through improvements, missiles are capable of directly communicating with satellites or unmanned aircraft. After that, contact is achieved with surface commanders. Missiles are also capable of carrying out communications with manned aircraft. The realization of real time transmissions is capable of letting commanders do evaluations of the status of targets destroyed by missiles, and, in conjunction with this, letting missiles reaim at targets during flight. It is also possible to control specially designated attack points associated with missiles aiming at targets. Besides carrying out improvements on missiles themselves, research and improvements will also be carried out on their mission planning systems in order to make them adapt to the requirements of new guidance methods.

Besides long term plans to improve Tomahawk missiles, the first batch of first generation Block 3 model Tomahawk missiles are just in the midst of testing. Improvements made in Block 3 model missiles include:

using global positioning system (GPS) guidance receivers to replace terrain matching and (or) digital scene matching area correlators (DSMAC). However, if DSMAC positioning is canceled and only GPS guidance is used, missile attack precisions will very, very greatly decrease;

opting for the use of improved DSMAC which is capable of making use of more scenes;

reducing warhead weights and volumes, thereby making it possible to carry more than 110 kilograms of propellant, making the range increase. However, combat power does not change;

Tomahawk Missile in the Process of Launch

improving control software associated with missiles reaching targets raising the precision of coordination between Tomahawk missiles and manned aircraft during combined operations;

Block 3 type Tomahawk missiles opting for the use of one rocket booster unit which has gone through improvements and one Weilianmusi (phonetic) Co. F-107-WR-102 large thrust engine unit. Due to added propellant, Block 3 type Tomahawk missile range is capable of reaching 1700-1850km. However, Block 2 model Tomahawk missiles only reach 1300km.

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